3D Reconstruction with Tango

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Contents

Problem statement and motivation

The Tango SDK

3D reconstruction - data structures & algorithms

Applications

Developer tools

Problem formulation

Goal: Create accurate, textured 3D models of indoor spaces

- real-time, on mobile device
- offline, in the cloud

Motivation

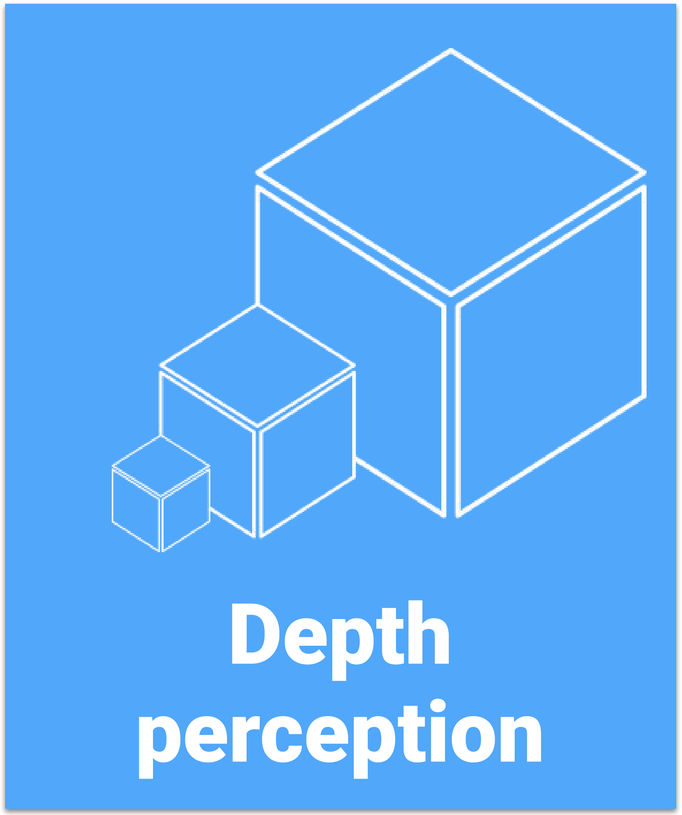
- immersive VR / AR - gaming, professional apps
- large scale maps, floorpans - navigation

Problem formulation

Challenges:

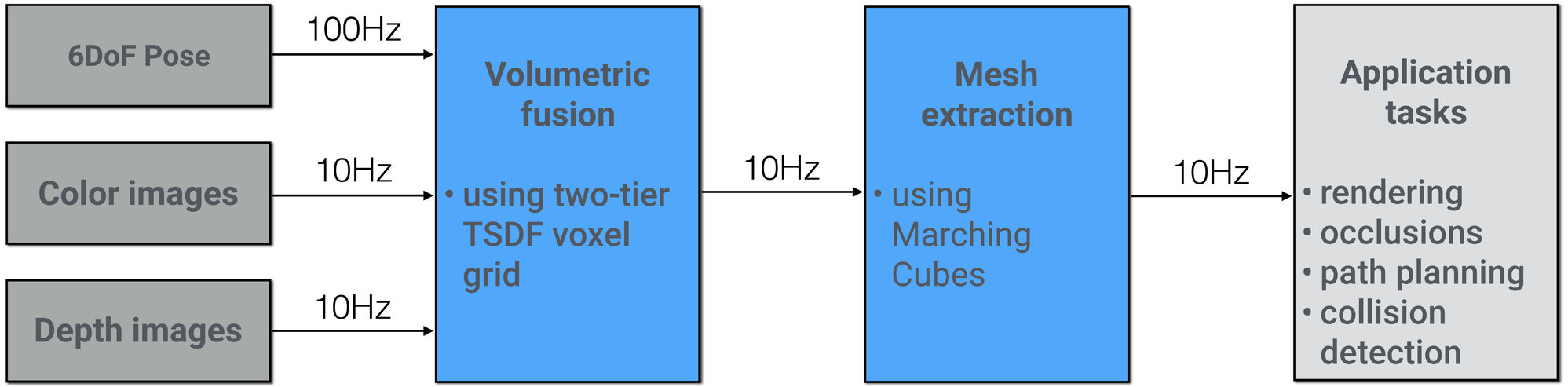
- Partial, noisy depth data
- Memory and computational constraints
- Platform diversity

Tango software stack



Tango 3D reconstruction

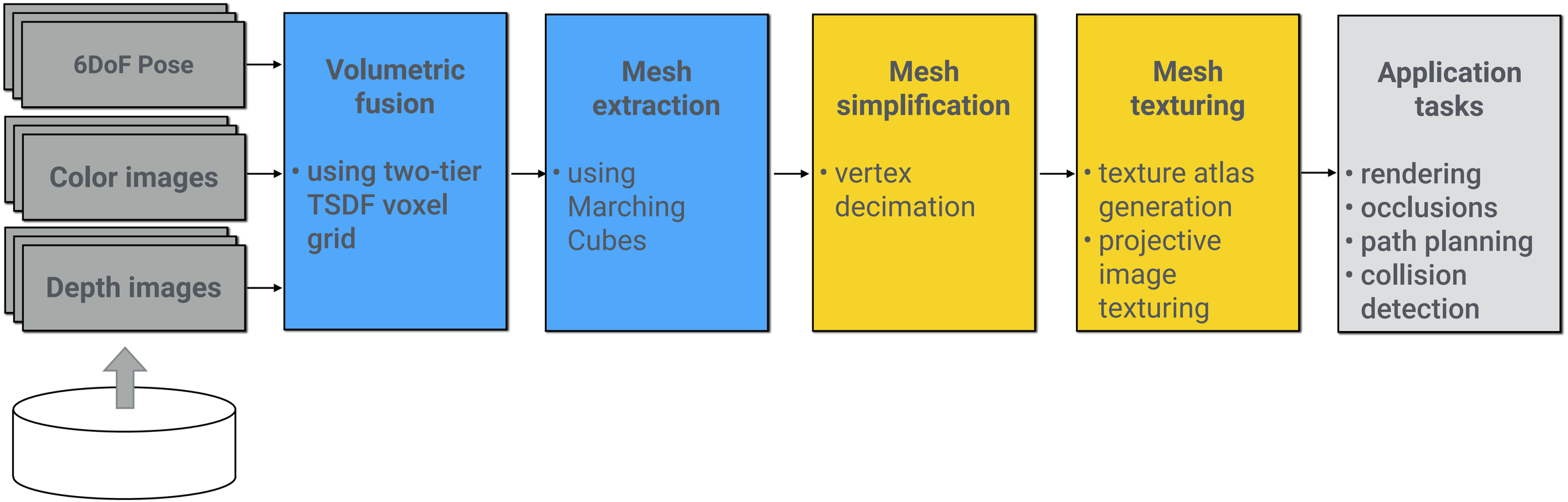
Real-time, online process



Klingensmith, Matthew, et al. "Chisel: Real Time Large Scale 3D Reconstruction Onboard a Mobile Device using Spatially Hashed Signed Distance Fields." Robotics: Science and Systems XI (2015).

Tango 3D reconstruction

Offline process



Signed Distance Function (SDF)

Represent space using **voxel grid**

Voxel contains signed distance function to nearest surface (**SDF**)

Only update near surface - estimate truncated function (**TSDF**)

Grid is updated by fusing depth readings (using running **weighted average** filter)

3	**3**	**3**	**3**	**3**	**3**	**3**
3	2	2	2	2	2	2
3	2	1	1	1	1	1
3	2	1	0	0	0	0
3	2	1	0	-1	-1	-1
3	2	1	0	-1	-2	-2
3	2	1	0	-1	-2	-3
3	2	1	0	-1	-2	-3

Curless, Brian, and Marc Levoy. "A volumetric method for building complex models from range images." Proceedings of the 23rd annual conference on Computer graphics and interactive techniques. ACM, 1996.

Signed Distance Function (SDF)

Surface of objects is represented by the **zero-isosurface** in voxel grid

Traversing the isosurface is done using **Marching Cubes**

Output is a **triangle mesh**

3	**3**	**3**	**3**	**3**	**3**	**3**
3	2	2	2	2	2	2
3	2	1	1	1	1	1
3	2	1	0	0	0	0
3	2	1	0	-1	-1	-1
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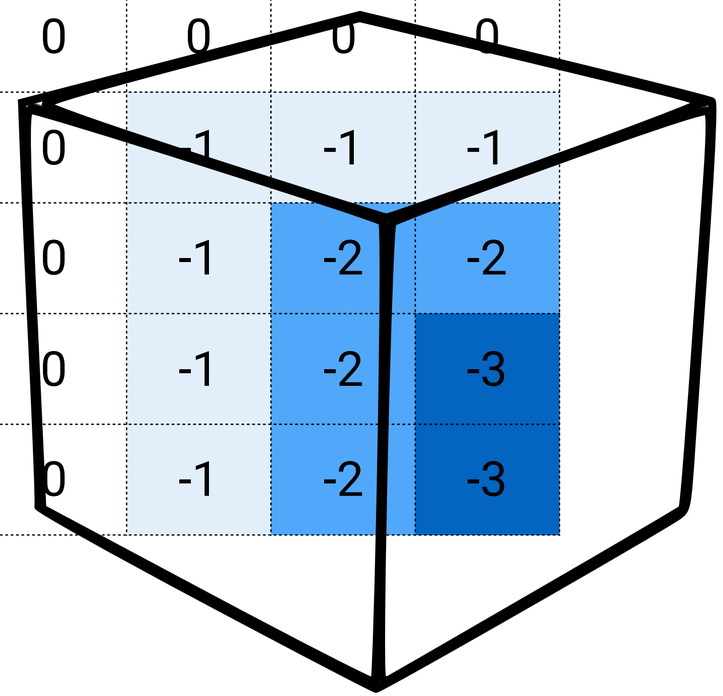
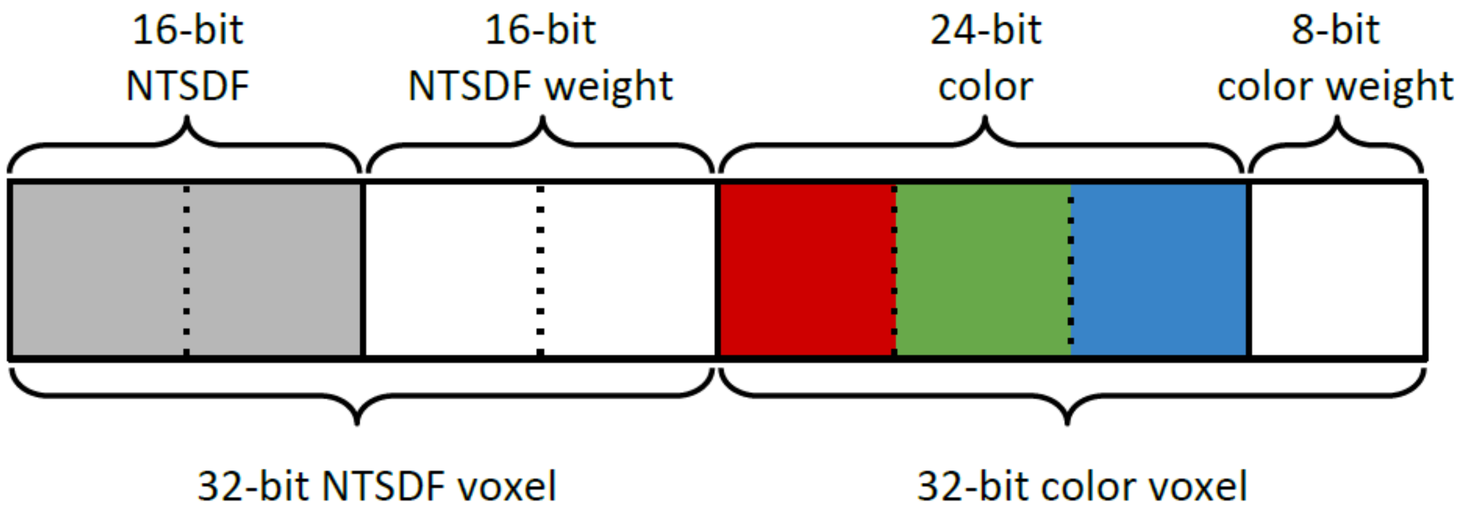


Curless, Brian, and Marc Levoy. "A volumetric method for building complex models from range images." Proceedings of the 23rd annual conference on Computer graphics and interactive techniques. ACM, 1996.

Voxel memory layout

64-bit per voxel (includes TSDF value, color value, filter weights)

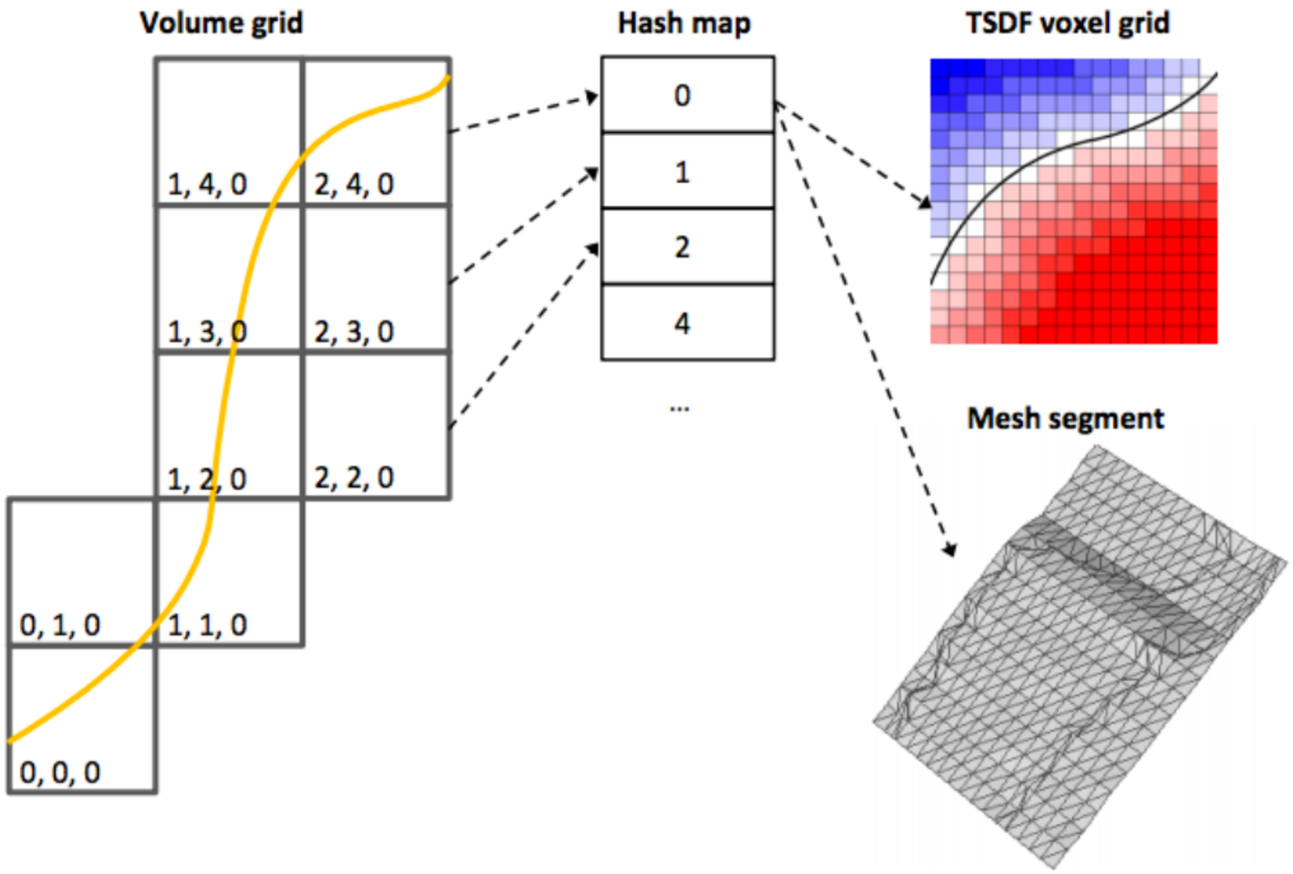


Dynamic Two-Tier TSDF voxel grid

Single TSDF grid for the entire scene would require **too much memory**

Hierarchical grid - larger **volumes** contain sub-grids

Volumes are sparsely allocated, and indexed by a **hash map**

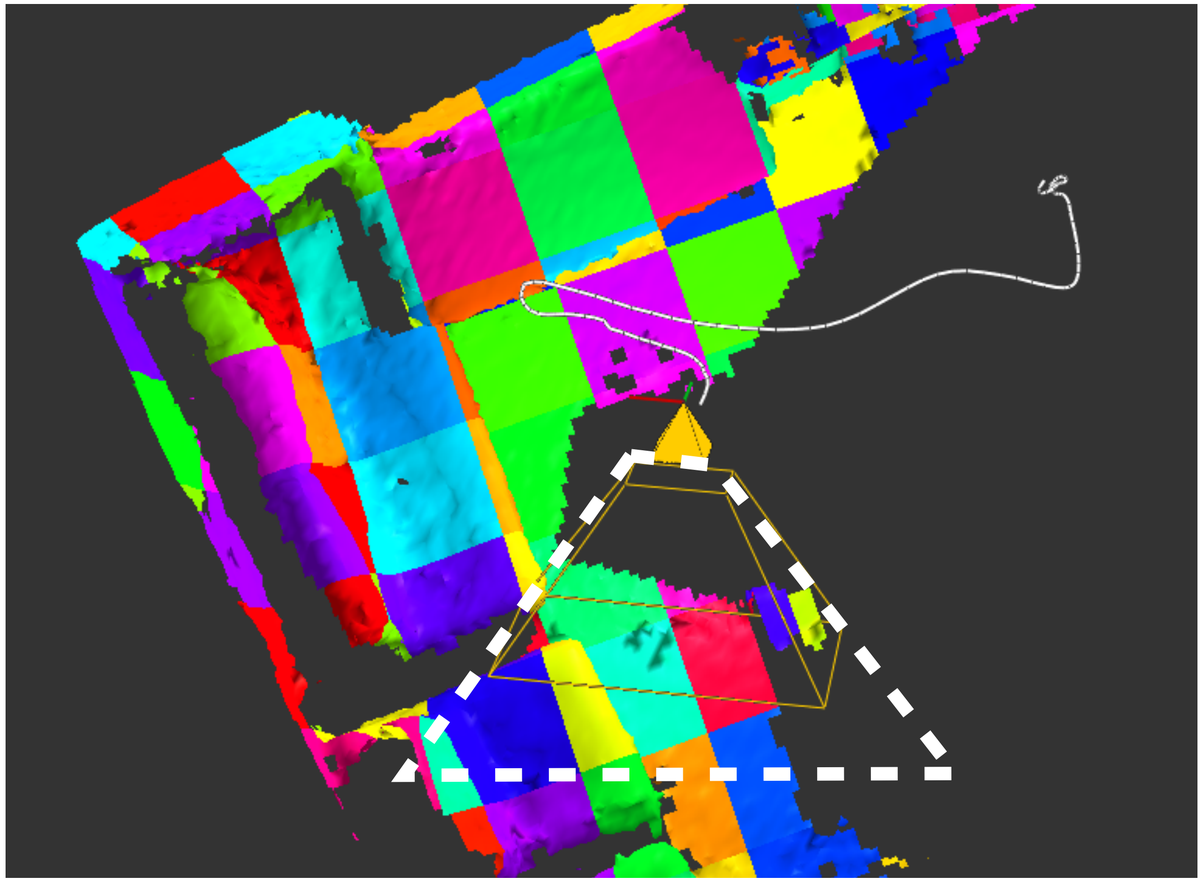


Nießner, Matthias, et al. "Real-time 3D reconstruction at scale using voxel hashing." ACM Transactions on Graphics (TOG) 32.6 (2013): 169.

Local frustum culling

When adding new observation, do intersect the **depth camera frustum** with the coarse volume grid

New volumes are allocated on-demand



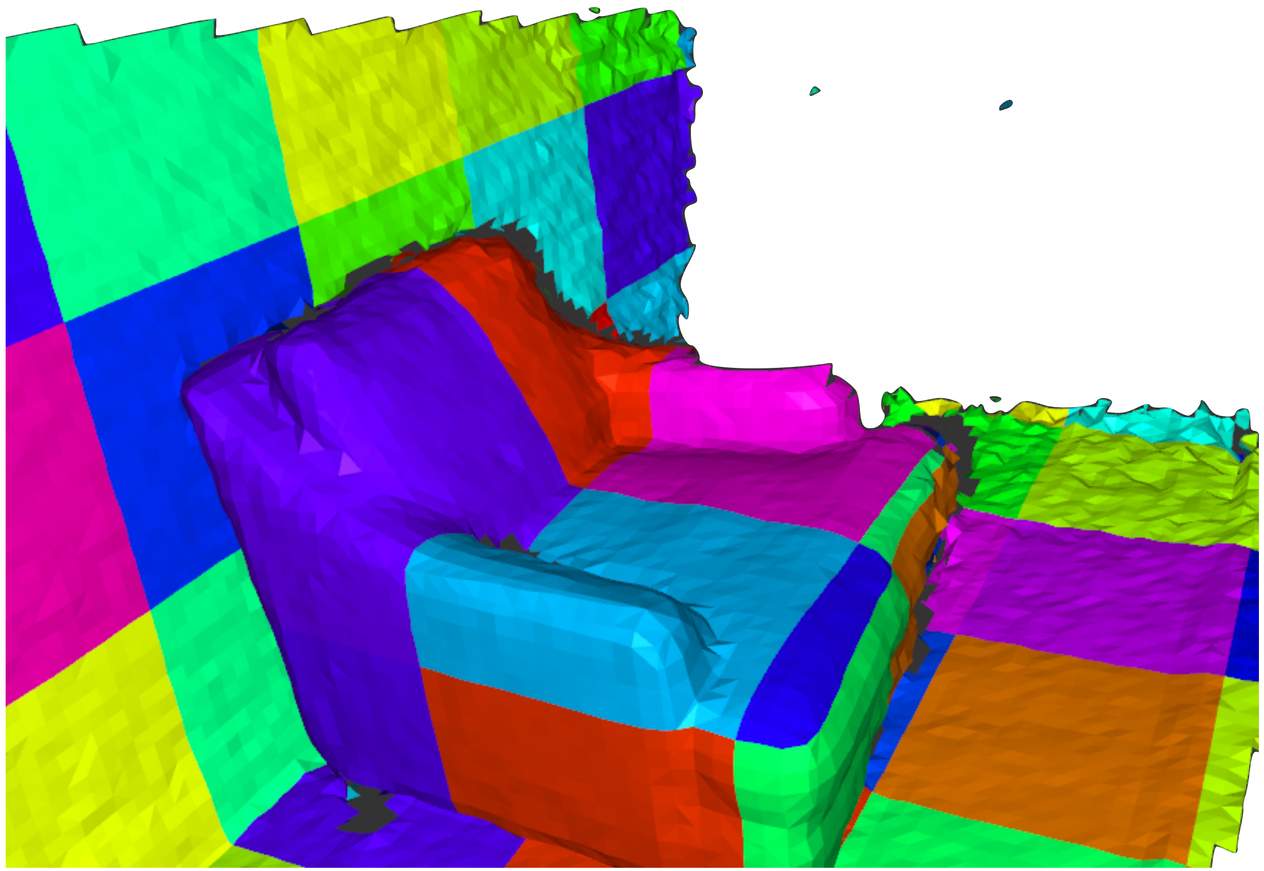
Klingensmith, Matthew, et al. "Chisel: Real Time Large Scale 3D Reconstruction Onboard a Mobile Device using Spatially Hashed Signed Distance Fields." Robotics: Science and Systems XI (2015).

Local frustum culling

Only intersected volumes receive TSDF updates

Only intersected volumes have their mesh segments re-extracted

Allows building of large models while updating and streaming **only local segments**



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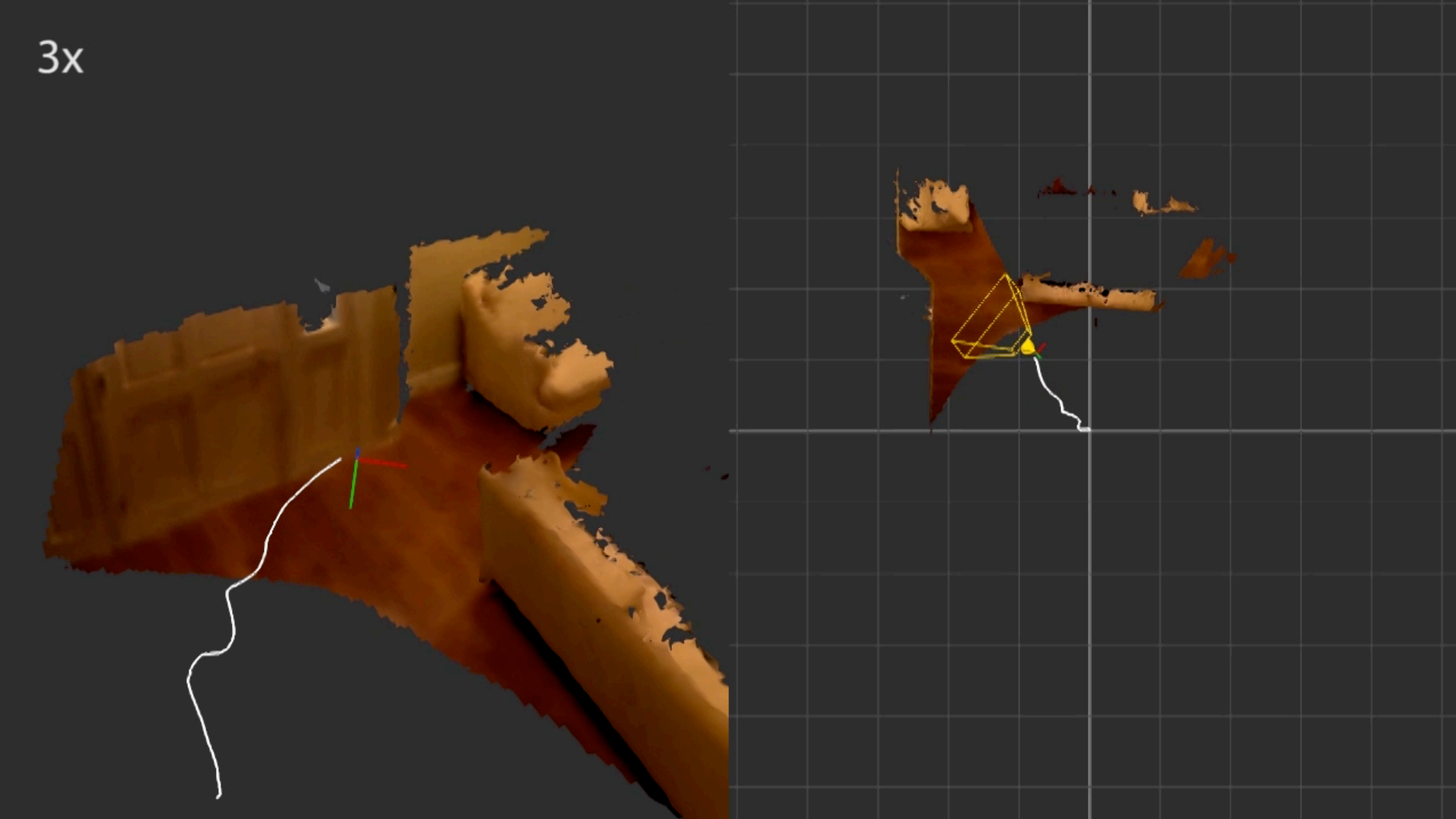
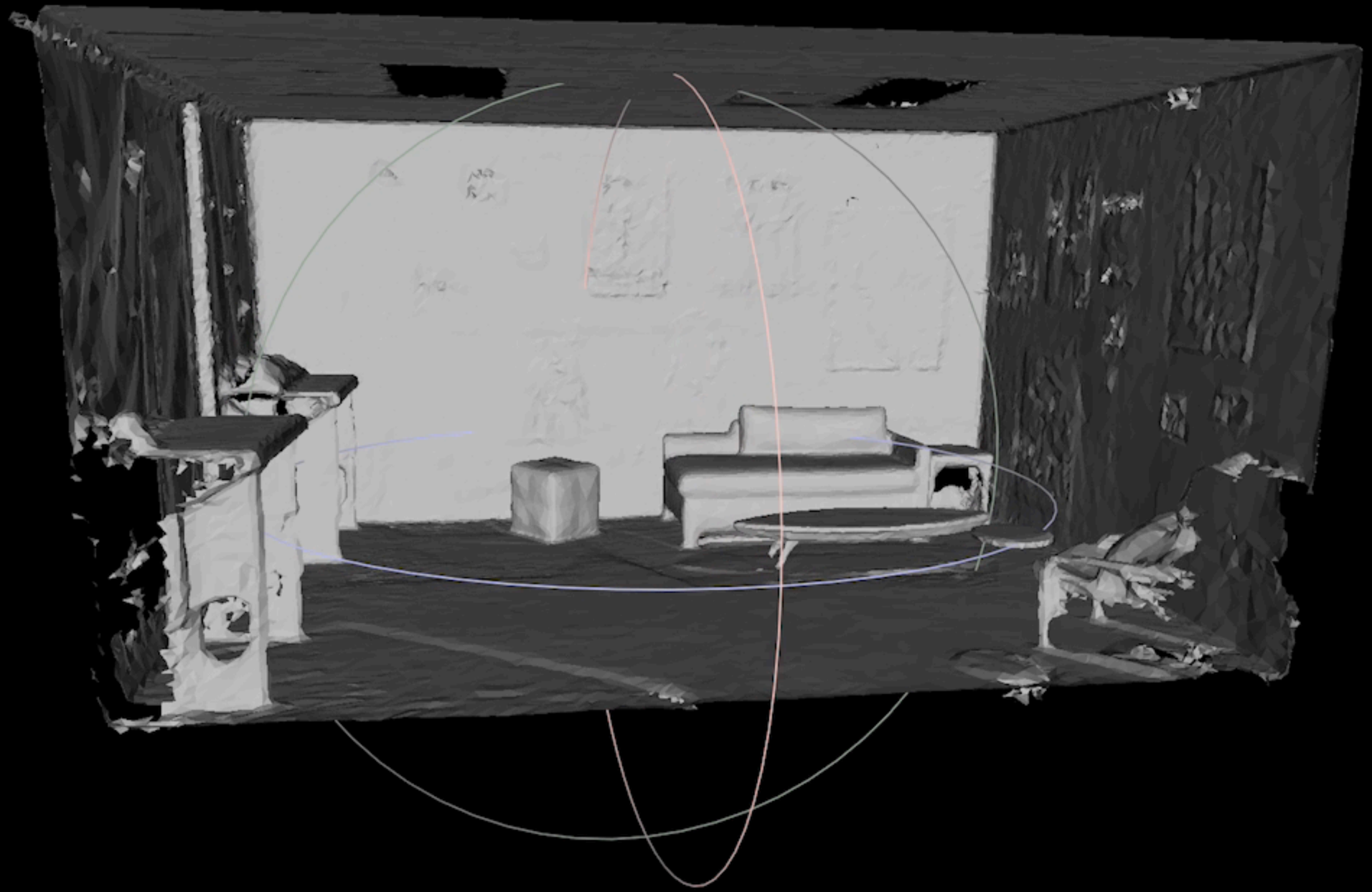
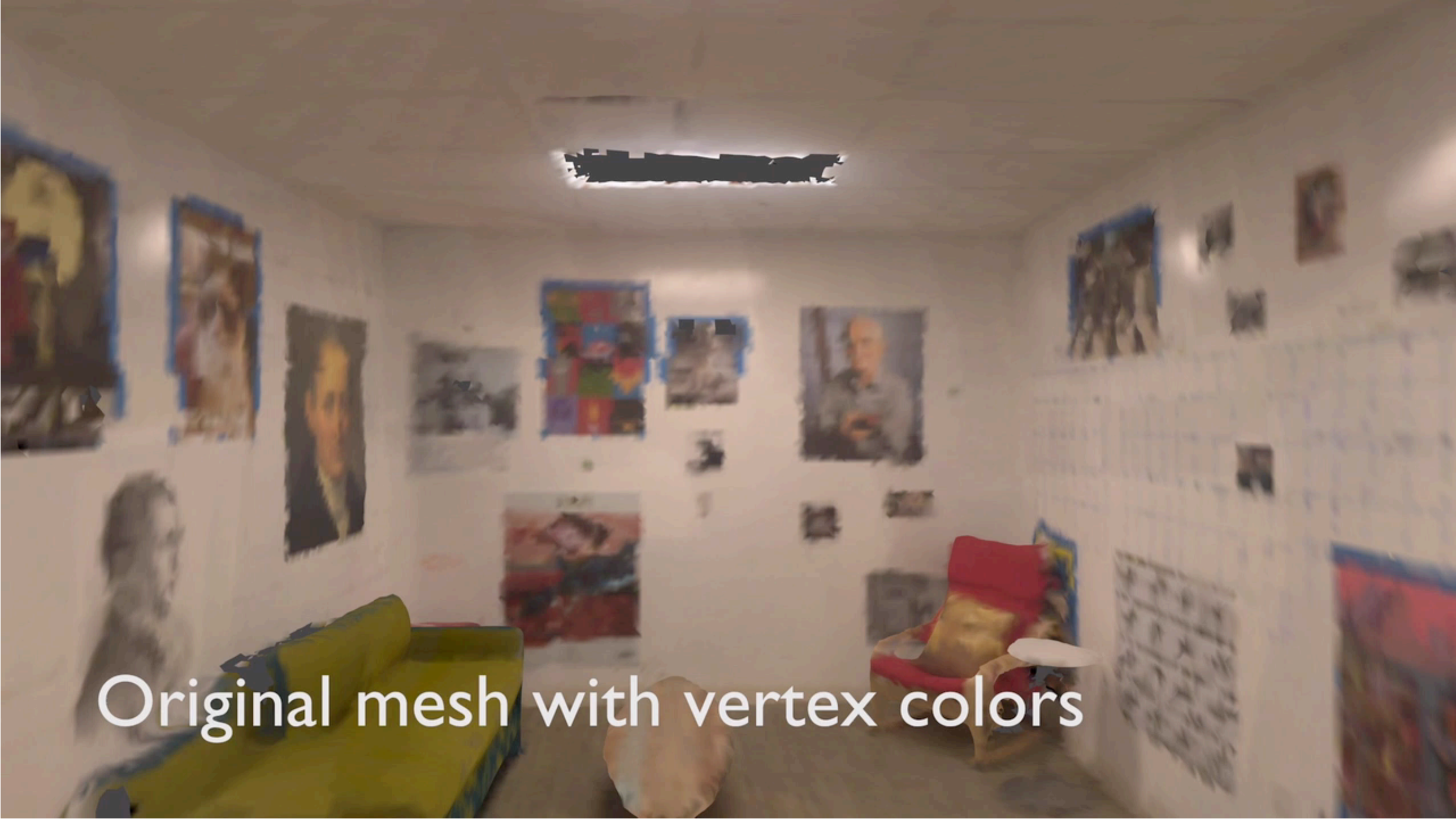
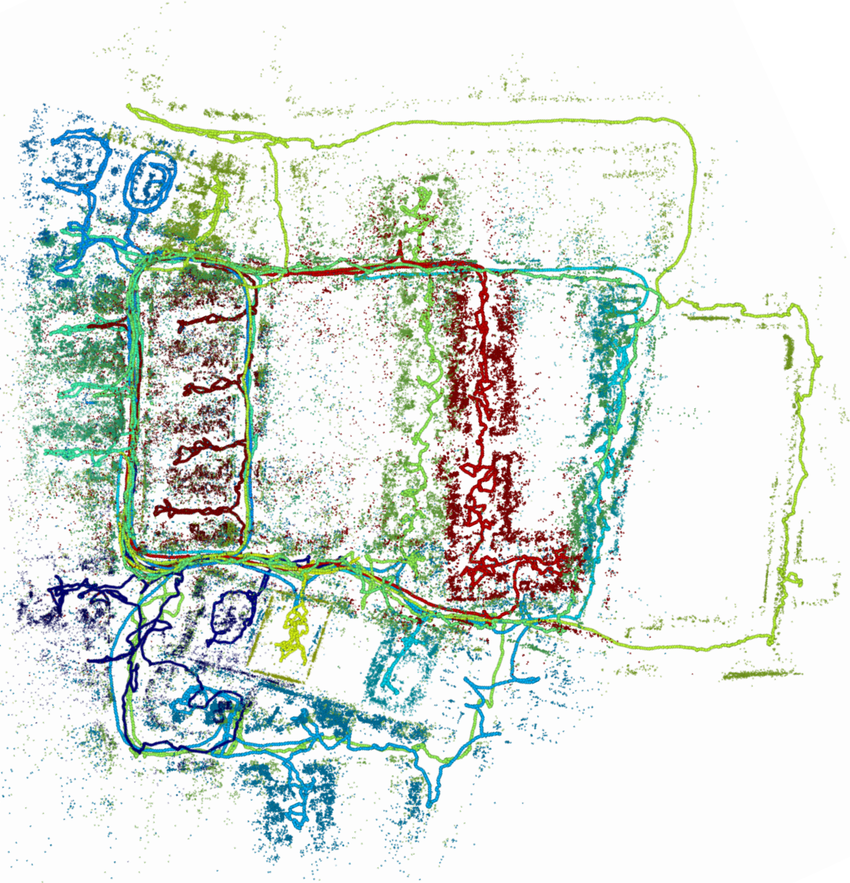

3x

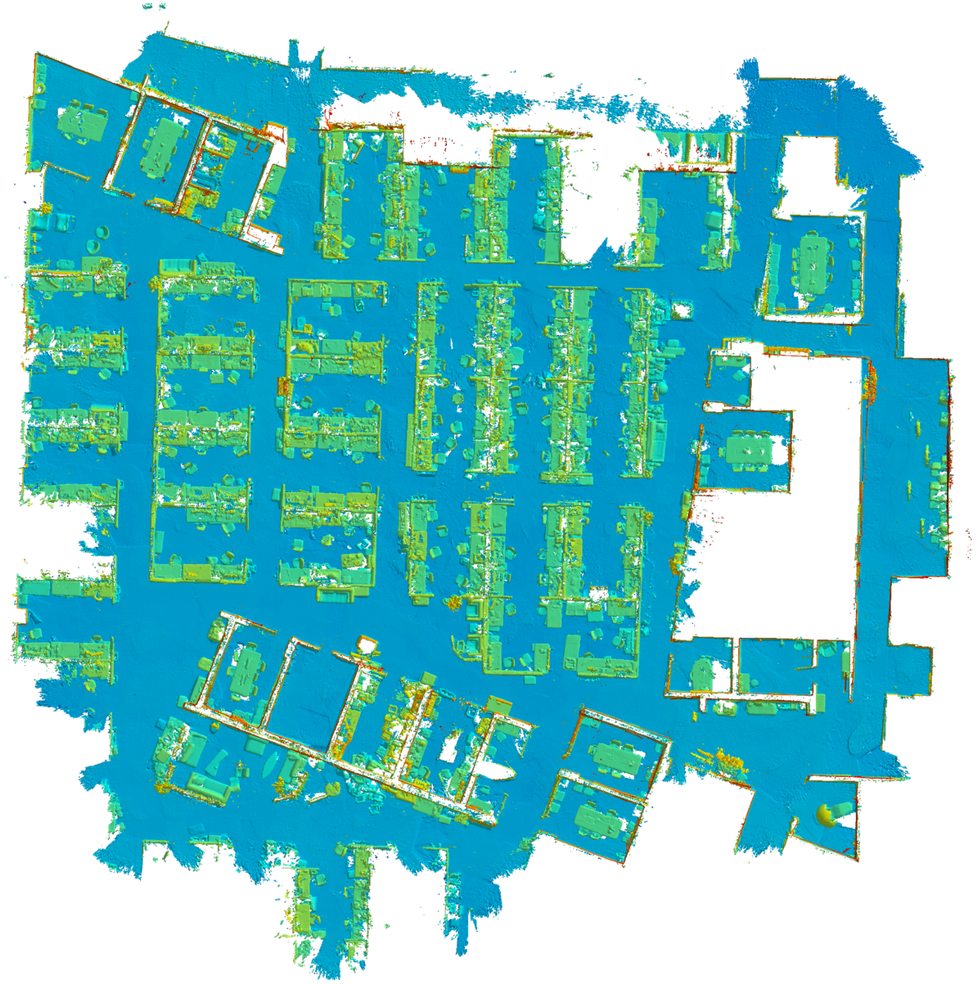



Original mesh with vertex colors

Large-scale reconstruction

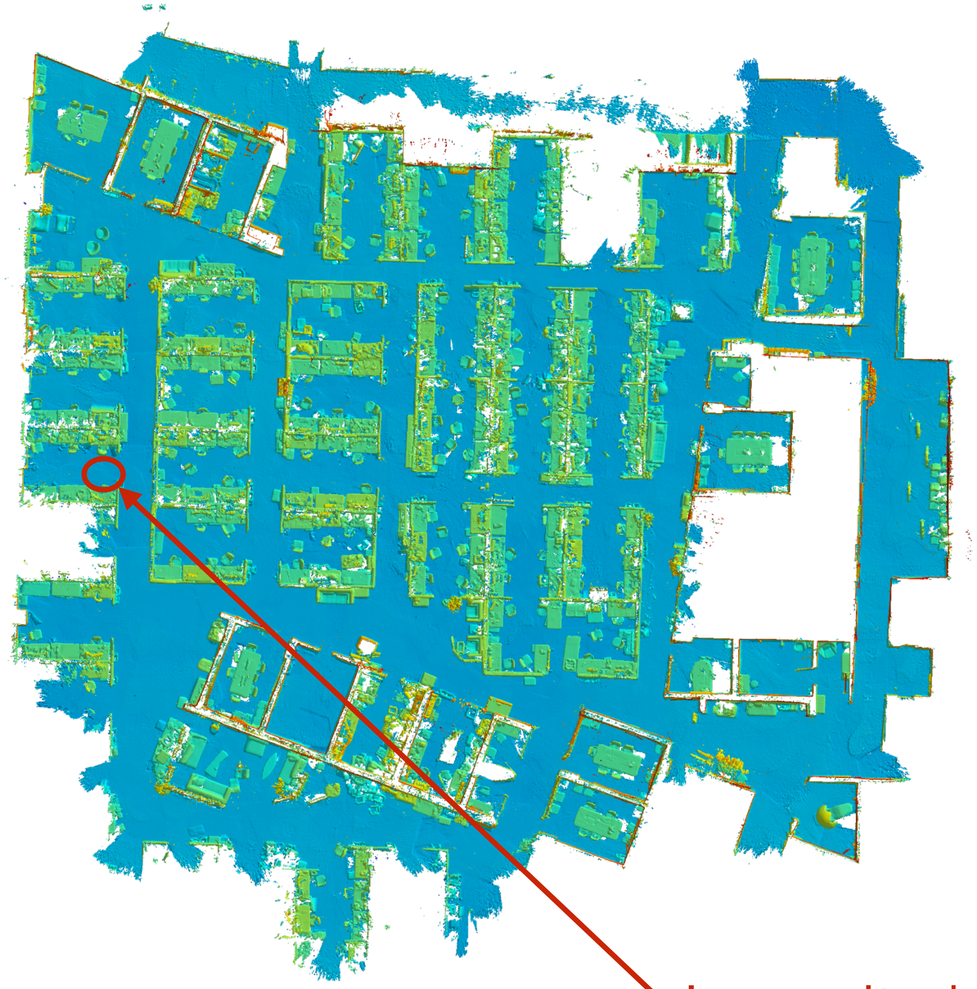


25 individual trajectories (~3 hrs)
Co-located using area learning



Final 3D map (false color by height)

Large-scale reconstruction



Developer tools

Tango Client API

- C / Java / Unity
- 6DoF pose, images, depth

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Tango 3D Reconstruction API

- C / Java / Unity
- provides textured 3D meshes

Developer tools

Constructor

- Android app for building and sharing 3D models

Tango Client API

- C / Java / Unity
- 6DoF pose, images, depth

Tango 3D Reconstruction API

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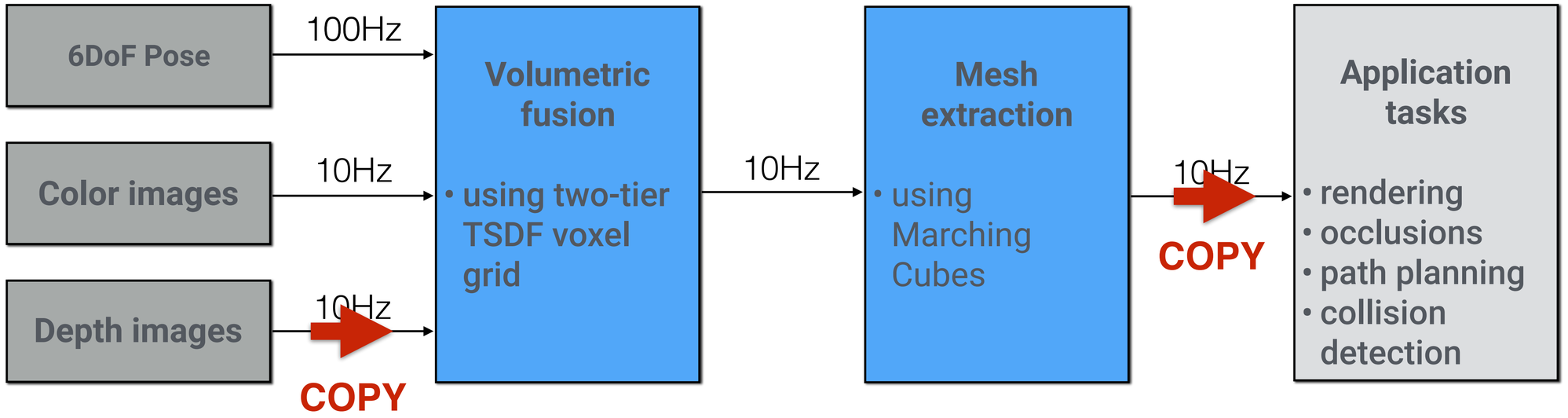
GPU implementation

If no shared memory between CPU & GPU, copying data is a bottleneck



Depth images as graphics texture?
Collision calculations on graphics hardware?

Thank you!
Q&A

Ivan Dryanovski, Google Inc.